DTU Library

Optical spatial filtering velocimetry sensor for vibration measurements

Jakobsen, M.L.; Larsen, H.E.; Hanson, Steen Grüner

Published in:
Final programme and abstract book

Publication date:
2004

Document Version
Publisher's PDF, also known as Version of record

6189-47, Session 10

Optical spatial filtering velocimetry sensor for real-time in-plane vibration control

M. L. Jakobsen, H. E. Larsen, S. G. Hanson, Risø National Lab. (Denmark)

We present a compact, non-contact, low-cost optical sensor for real time detection and active vibration control of mechanical devices based on speckle translation. The sensor carries out single-point measurements of sub-micron, in-plane translational vibration of a solid structure in real time.

The mechanical device is simulated by a metal plate standing on top of the membrane of a speaker. In between the plate and the mount on the membrane, a piezo-electrical device is mounted for vibration compensation of the plate. When applying an alternating current to the coil, while the piezo-electrical device is deactivated, the plate will vibrate in the direction of the normal to the membrane surface. The sensor monitors the motion of the plate from a direction perpendicular to the normal to the membrane surface. This results in in-plane observation of the vibration of the target. When activating the piezoelectrical device via an error signal from the sensor, the vibration of the plate can be compensated.

The plate is made of aluminium, and has a raw surface finish after machining giving rise to a fully developed speckle field. The sensor illuminates the plate with coherent light, thus laser speckles and their dynamics can be observed from a distance. The light scattered from the surface propagates through an imaging system to a spatial filtering system, based on a lenticular array [1] and a spherical lens, which implement a spatial, narrow band-pass filter. The spatial filter extracts a given spatial frequency of the speckle pattern in terms of a quasi-sinusoidal spatial intensity distribution. At the detector plane, the dynamic quasi-sinusoidal intensity distribution is monitored at various phase steps, thus two differential sensor signals with a mutual phase shift provide the real-time phase information of the spatial frequency component to the electronic-processing device.

The processing device samples the two phase-shifted signals with two 30MS/s analogue to digital converters and calculates the resulting vibration of the plate. Then, a digital to analogue converter produces an error signal, providing the analogue feedback to the piezo-electric device counter acting the membrane movement, thus achieving active vibration control.

The presented imaging configuration facilitates the construction of a sensor with no direct sensitivity to any superimposed rotational vibration. Replacing the imaging system with a Fourier transforming system instead, the sensor will allow measurement of rotational vibration without direct sensitivity to any translational vibration. The calibration of the sensor is independent of the optical wavelength to the first order. Therefore, the sensor is highly stable towards thermal drifts.

The optical sensor and the processing device will be demonstrated for real-time in-plane vibration detection. Considering only the optical sensor and its analogue electronics we have a bandwidth 160 kHz for the given design, and we expect [2] within this bandwidth a resolution in the amplitude of a vibration down to at least 6 nm. The practical limitations to the ‘real-time’ vibration detection will be described with regards to the speed of the processing device, and the use of a piezo-electrical device for vibration control.

[1] Jakobsen, M. L. and Hanson, S. G., Lenticular array for spatial filtering of laser
speckle from solid surfaces, Applied Optics, 43, (24), 4643-4651 (2004).

[2] Jakobsen, M. L., Larsen, H. E. and Hanson, S. G., Optical spatial filtering velocimetry sensor for submicron, in-plane vibration measurements, Journal of Optics A: Pure and Applied Optics, 7, S303-S307 (2005).